Abstract   The application of electrified railway directly promotes relevant studies on pantograph-catenary interaction. With the increase of train running speed, the operating conditions for pantograph and catenary have become increasingly complex. This paper reviews the related achievements contributed by groups and institutions around the world. This article specifically focuses on three aspects: The dynamic characteristics of the pantograph and catenary components, the systems’ dynamic properties, and the environmental influences on the pantograph-catenary interaction. In accordance with the existing studies, future research may prioritize the task of identifying the mechanism of contact force variation. This kind of study can be carried out by simplifying the pantograph-catenary interaction into a moving load problem and utilizing the theory of matching mechanical impedance. In addition, developing a computational platform that accommodates environmental interferences and multi-field coupling effects is necessary in order to further explore applications based on fundamental studies.

Keywords   electrified railway, pantograph and catenary interaction, contact force variation, moving load problem, mechanical impedance, multi-field

1 Introduction

The performance of a high-speed train (HST) is subjected to the influences arising from the wheel-rail interaction, the pantograph-catenary interaction, and the aerodynamic resistances (Fig. 1). As one of the basic mechanics problems of the HST dynamics, the pantograph-catenary interaction plays an important role in HST operation, because it supplies the electric resource of traction power for electric rail vehicles. Thus, the operational stability of an HST is highly dependent upon the performance of the pantograph and catenary system.

Figure 2 illustrates two types of catenary system: Simple and stitched. Figure 2(a) presents the simple catenary consisting of a messenger wire, a contact wire, droppers, registration arms, and support brackets. The messenger wire, which is suspended by the brackets, is connected to the contact wire via equally or non-equally placed droppers. The registration arms, installed on the support brackets, are used to clamp the contact wire to form a zigzag pattern above the centerline of the tracks. Compared with the simple catenary, an elastic dropper is installed between two adjacent spans for the stitched catenary (Fig. 2(b)). This kind of improvement not only increases the uniformity of the vertical elasticity within a catenary span but also adds energy transmission passage between adjacent spans. When a stitched catenary is subjected to external excitations, the mechanical energy is transmitted to the whole catenary rapidly in the form of an elastic wave, thereby reducing the interruption from local elastic wave to the contact state between the pantograph and catenary. As a result, the performance of the stitched catenary is always favorable. However, compared with the simple one, the stitched catenary has less popularity and application because of the complexity of its construction and maintenance.

The pantograph can be classified into three different types: Four-bar linkage, diamond, and T-type pantographs. The diamond pantograph (Fig. 3(a)) is not commonly used because it has the potential to break the catenary when it is out of order. The T-type pantograph (Fig. 3(b)) has a simple structure with good aerodynamic performance and is mainly used in the railway lines that prefer a low working height, such as the Japanese Shinkansen. The most popular pantograph consists of a four-bar linkage, a balance bar, and a current collector (Fig. 3(c)). The balance bar connects the current collector to the four-bar linkage and keeps it moving in a vertical trajectory. As the constraint between the current collector and the balance bar can be designed with different types, the four-bar linkage pantograph has many variations and has been widely used.
all over the world. Actually, regardless of the type of pantograph, it is generally used to lift the current collector to the desirable working height, thus putting it into contact with the catenary wire and obtaining the current transmission.

Actually, the pantograph and catenary interact in a multi-physical environment. Many types of energy transformation occur on the contact interface, including mechanical, heat, and electric energies. Consequently, the performance of the system depends on the multi-coupled interactions among the mechanical properties (general and fluid mechanics) and electrical and thermal effects. However, no matter what the subject is, a stable contact state between the pantograph and catenary is preferred. As the stability of the contact state depends on the lift force in the working height of a pantograph, good mechanical properties serve as the bases of operation of the pantograph-catenary system. In this paper, we do not pay attention to the content outside the pantograph and catenary dynamics, such as the electrical contact [2–6], friction and wear [7–10], heat effect [11], and simulation and test technology of the pantograph-catenary system. More details can be seen from the relevant reviews [12,13].

When a moving pantograph passes through a discontinuous node upon the contact wire, i.e., the clamp position, this can lead to a transition radiation of the elastic wave on the catenary [14]. This kind of elastic wave conversely interrupts the vibration of the moving pantograph, resulting in the dynamic interaction between the pantograph and catenary. In addition, the ambient wind and the vehicle body movements caused by the degraded track

Fig. 2 Different catenary systems. (a) Simple catenary; (b) stitched catenary

Fig. 3 Different types of pantograph. (a) Diamond pantograph-ATR90; (b) T-type pantograph-Shinkansen Serie 500; (c) four-bar linkage pantograph-SSS400